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What Lurks in the Martian Rocks and Soil? Investigations of Sulfates, Phosphates, and Perchlorates

Dissolution rates of amorphous Al- and Fe-phosphates and their relevance to phosphate mobility on Mars†

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Abstract

Phosphate is an essential nutrient for life on Earth, and therefore if life exists or ever existed on Mars it may have required phosphate. Amorphous Al- and Fe-phosphates rapidly precipitate from acidic solutions and amorphous Al-phosphates likely control phosphate concentrations in some natural waters on Earth. The amorphous fraction of martian soils has also been shown to be enriched in P, and amorphous phosphates are therefore also likely important in the phosphate cycle on Mars. Despite this importance, however, few dissolution rates exist for amorphous Al- and Fe-phosphates. In this study, dissolution rates of amorphous Al- and Fe-phosphates were measured in flow-through reactors from steady state concentrations of Al, Fe, and P. A pH-dependent rate law, $\log R = \log k - n\text{pH}$ was determined from the dissolution rates, where R is the dissolution rate, k is the intrinsic rate constant, and n is the reaction order with respect to H^+. For amorphous Al-phosphate, $\log k = -6.539 \pm 1.529$ and $n = 2.391 \pm 0.493$. For amorphous Fe-phosphate, $\log k = -13.031 \pm 0.558$ and $n = 1.376 \pm 0.221$. The amorphous Al-phosphate dissolves stoichiometrically under all experimental conditions measured, and the amorphous Fe-phosphate dissolves non-stoichiometrically, approaching stoichiometric dissolution as pH decreases, due potentially to Fe oxyhydroxides precipitating and armoring grain surfaces. Perhaps due to these effects, amorphous Al-phosphate dissolution rates are approximately three orders of magnitude faster than the amorphous Fe-phosphate dissolution rates measured under these experimental conditions. Amorphous Al-phosphate dissolution rates measured in this study are also faster than published dissolution rates for the crystalline Al-phosphate variscite. The rapid dissolution rates measured in this study therefore suggest that, if these phases are present on Mars, phosphate would be rapidly released into acidic environments.

Keywords: Phosphate, Mars, mineral dissolution, kinetics, habitability, astrobiology, amorphous phases, synchotron